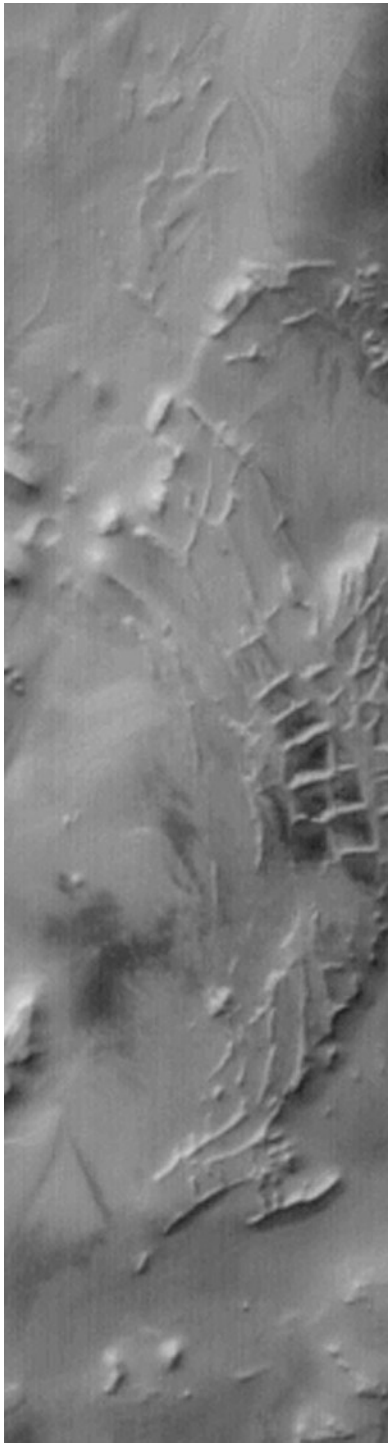

NASA Critical Facilities Maintenance Assessment

Second Annual International Maintenance Excellence Conference (Univ. of Toronto)

Note to Reviewers: This presentation will be reformatted to match the IMEC presentation template

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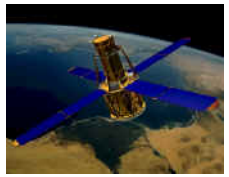
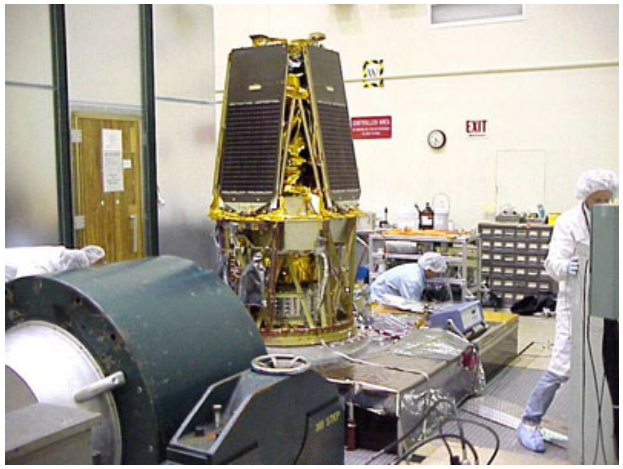
November 1, 2006

HESSI Spacecraft Overtest Incident

- Critical Facilities Maintenance Assessment (CFMA) was first implemented by NASA following the March 2000 overtest of the High Energy Solar Spectroscopic Imager (HESSI) spacecraft



- A *sine burst* dynamic test using a 40 year old shaker failed. Mechanical binding/slippage of the slip table imparted 10 times the planned force to the test article
- There was major structural damage to HESSI
- The mechanical "health" of the shaker had not been assessed and tracked to assure the test equipment was in good working order
- Similar incidents have occurred at NASA facilities due to inadequate maintenance (e.g., rainwater from a leaky roof contaminated an assembly facility that housed a spacecraft)



Preparations for HESSI dynamic test

- The HESSI incident alerted NASA to the urgent need to identify inadequacies in ground facility readiness and maintenance practices

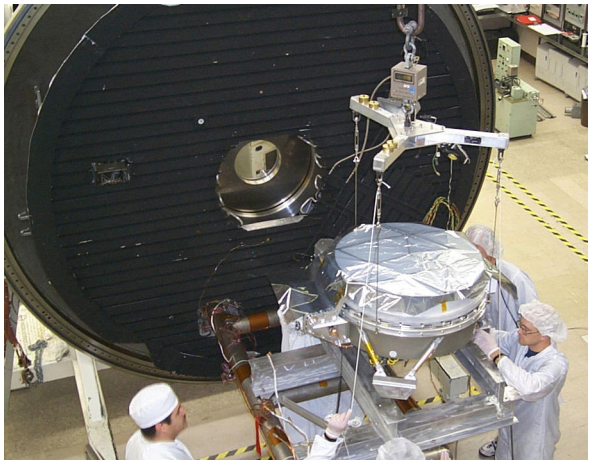
High Unit Value Products

- The consequences of failures of ground facilities that service these NASA systems are severe due to the **high unit value** of NASA products

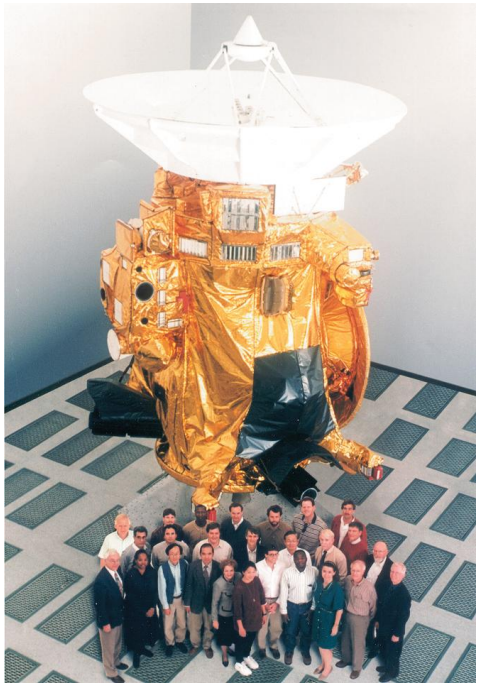
Ground Facilities: A Maintenance Challenge

- Product development and operations depend on a vast network of ground facilities that are expensive to maintain.

Wind tunnels at NASA Ames Research Center include the world's largest— the 80' x 120'



Entire spacecraft are tested under simulated space conditions in vacuum chambers up to 100 ft. in diameter

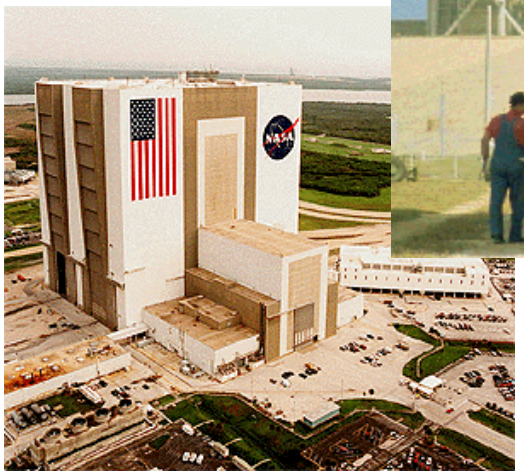


Clean rooms, acoustic chambers, and solar radiation simulators could accommodate the 3-ton Cassini Spacecraft

… A Maintenance Challenge (Cont.)

- Some of these critical facilities may represent irreplaceable national assets

NASA Deep Space Network communications facilities located in the Mojave Desert (California), Spain, and Australia are essential to spacecraft commanding and science data return



The Vertical Assembly Building (VAB) at Kennedy Space Center is one of the largest buildings in the world

The Crawler-Transporter carries the mobile launcher platform and the Space Shuttle over a specially constructed road to the launch complex

Critical Facilities Maintenance Assessment

- The HESSI overtest incident alerted NASA to the substantial risks of utilizing aging industrial facilities for the development of high value, one-of-a-kind products.
- **NASA Response:** Conducted *Critical Facilities Maintenance Assessment* (CFMA) to identify inadequacies in ground facility readiness that could affect the safety of the public, the NASA workforce, flight hardware, and other critical equipment and property
- **Methodology:** Prepare and implement an institutional plan for the comprehensive assessment of NASA-critical facilities and equipment. This involves:
  1. An inventory of critical facilities and equipment.
  2. Comprehensive assessment of failure modes for critical equipment.
  3. Establishment of appropriate Reliability Centered Maintenance (RCM) methods and acquisition of necessary Predictive Testing and Inspection (PT&I) equipment.
  4. Implementation of RCM using a Computerized Maintenance Management System (CMMS) and appropriate performance metrics
  5. Training at each of the 10 NASA field centers in RCM and CFMA procedures.

  Assessment and upgrade of maintenance practices is established as a continuous process.

Step 1: Facility Inventory & Audit

- Initial CFMAs were performed at the NASA field centers and remote installations beginning 6 months after the HESSI mishap
- The first step is Facility Inventory and Audit:
  1. NASA equipment and facilities at each NASA field center are inventoried and ranked by their relative criticality.
  2. Each critical facility is audited for compliance with maintenance policies and procedures
  3. The audit team also reviews maintenance procedures for adequacy, observes operations and housekeeping activities, reviews maintenance records, and conducts interviews to assess the level of formal training on maintenance techniques, including RCM
  4. Deficiencies and remedial plans are documented in an institutional closed-loop corrective action system, and a summary report is issued on the general state of repair at the NASA field center

Note: CFMA is only performed for in-house facilities. However, contractor proposals and operations should be reviewed for the maturity of their maintenance practices, and opportunities to share data should be pursued

Step 2: Failure Mode Assessment

- Each NASA field center conducts an informal assessment to determine and document the principal latent failure modes and the consequences of failure for the inventoried facilities.
- This assessment looks like a high level fault tree (below), is limited to the major causes of concern, and identifies where the failure modes are preventable by maintenance

• **Loss of Chamber Vacuum** – Caused by pump or valve failure • Preventable by maintenance – Caused by loss of electrical power • Only partially preventable by maintenance – Caused by broken window or feed-through penetration • Not preventable by maintenance – Possible types of damage to flight hardware • Corona discharge • Contamination – Protection of flight hardware • Vacuum failure alarm system • Spacecraft power cut-off pressure sensor system • Emergency power generator	• **Loss of Chamber Solar Simulation** – Caused by cooling water failure • Preventable by maintenance • Caused by loss of electrical power • Only partially preventable by maintenance – Caused by lamp explosion • Not preventable by maintenance – Possible types of damage to flight hardware • Exceed lower temperature limits – Protection of flight hardware • Over/under temperature alarm system • Spacecraft safing heaters • Emergency power generator • **(Next failure mode)**

Example: failure mode assessment for a (hypothetical) large space simulator

Step 3: Establishment of RCM Methods

- Evaluate the facilities' use of Reliability Centered Maintenance (RCM) and Predictive Testing and Inspection (PT&I) practices to control life-cycle costs, achieve the desired equipment availability, and maximize safety.
- The audit assesses the maturity of the following elements of each NASA center's RCM program
  1. Maintenance Philosophy
  2. Program Organization
  3. Performance Metrics
  4. Proactive Maintenance
  5. Use of PT&I Technologies
  6. Preventive Maintenance
  7. Training & Personnel Development

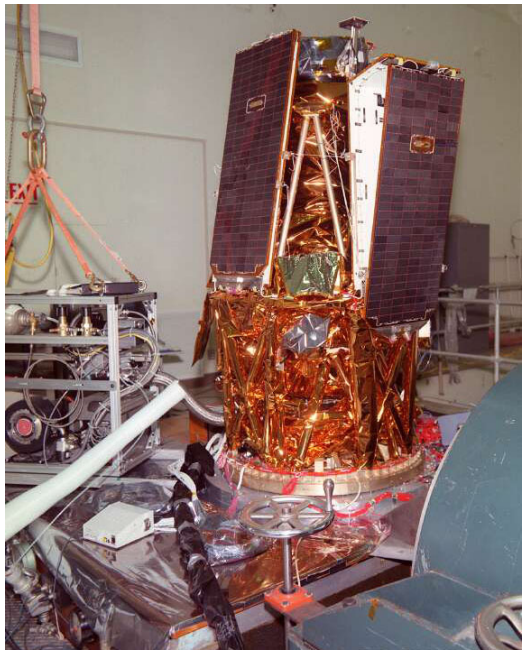
	RCM Program Elements						
Program/Organization	Maintenance Philosophy	Program Organization	Performance Measures (Metrics)	Proactive Maintenance	PT&I Technologies	Preventive Maintenance	Training & Personnel Development
Organization A	▼	▲	▼	▲	▼	▷	▼
Organization B	▼	▼	▼	▼	▼	▷	▷
Organization C	▼	▼	▲	▼	▼	▷	▼
Organization D	▼	▼	▼	▼	▷	▷	▼
Organization E	▲	▼	▼	▼	▼	▷	▼
Organization F	▼	▼	▼	▲	▼	▷	▼
Overall Center (Critical Facilities)	▼	▼	▼	▷	▼	▷	▼

Legend: ▲ Fully Mature ▷ Some Initiatives ▼ No Initiatives

- Issue a report to benchmark each center's progress with RCM and identify RCM improvement opportunities
- Review PT&I technologies currently in use across the NASA field center, and identify other opportunities for their application

Step 4: Implement CMMS

- Implement a Computerized Maintenance Management System (CMMS) across the NASA field center
  - Validates the critical equipment inventory and links it with data on the equipment's condition, maintenance activity, and operational history
  - Assists the NASA field center in scheduling and recording maintenance tasks, certifications and validations, PT&I applications, and RCM-based initiatives
- Derive a standard set of maintenance metrics, including RCM performance measurements and indicators, that reflect the health of the NASA center's critical facility maintenance programs



Test-induced damage to the HESSI spacecraft

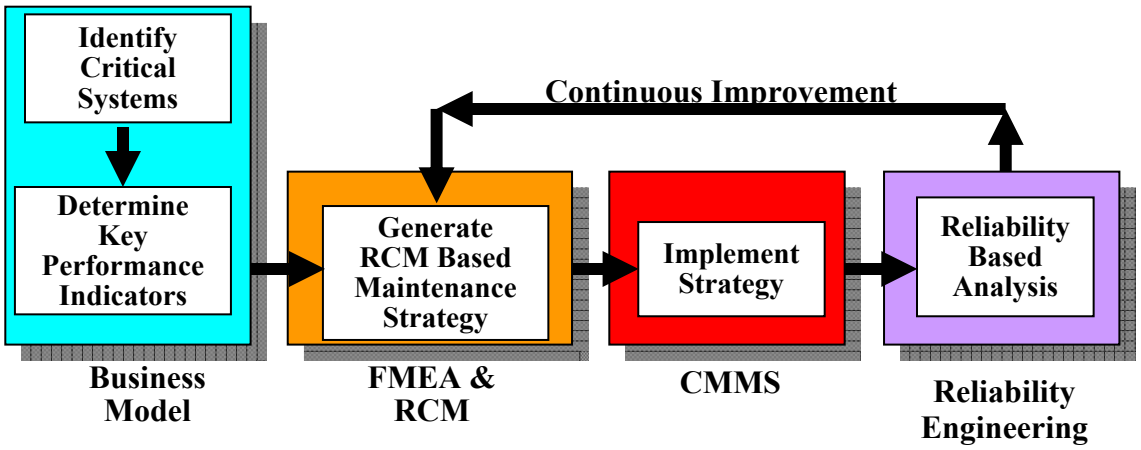
Step 5: Personnel Training

Jet Propulsion Laboratory
California Institute of Technology

- CFMA requires an assessment of existing RCM and PT&I training and of organization-wide training needs
- Prepare a plan for skill evaluation and training throughout the organization
  - Provide familiarization with RCM principles and Failure Mode and Effects Analysis
  - Priority for RCM training should be given to “RCM champions” within each maintenance organization, reliability engineers, maintenance managers, and craft and administrative support personnel.
  - Extend existing PT&I programs by providing PT&I training to technicians and analysts assigned to facilities that are not presently covered.
  - Conduct In-house seminars on best maintenance practices, RCM, and PT&I
  - Training records should be kept for both employees and contractor personnel.
  - The training program should also support continuous CFMA by training individuals in the CFMA facility assessment process

Summary

- CFMA provides a systematic methodology for evaluating the upkeep of high value assets and preventing deterioration that could damage high value products and injure personnel.
- CFMA emphasizes techniques such as RCM and PT&I to assure that maintenance of critical facilities and equipment is consistently and cost-effectively performed
- CFMA is best performed as a **continuous improvement process** involving periodic inventory of critical facilities and assessment of facility adherence to maintenance standards



The NASA Vision for Asset Management